SIGNATURE PAGE

Country: China

UNDP China

Project Title: Demonstration Project for Conversion from HCFC-22 Technology to ammonia/CO_2 Technology in the Manufacture Of Two-stage Refrigeration Systems for Cold Storage and Freezing Applications at Yantai Moon Group Co.Ltd.

UNDAF Outcome(s): Key UN conventions promoted; capacity improved fulfill their Obligations

Expected CP Outcome(s): Strengthened national capacity and empowerment of local Stakeholders in environmental management; successful phase out of Ozone-depleting substances being used by enterprises in various Industrial sectors

Expected CP Output(s): Policy makers and general public engaged to support UN conventions Implementation

Implementing partner: Ministry of Environmental Protection

Brief Description

This demonstration project, upon successful completion, will establish the suitability of Ammonia/CO_2 technology as a viable replacement for HCFC-22 technology in the manufacture of integrated two-stage refrigeration systems for cold storage and freezing applications at Yantai Moon Group Co. Ltd. The project will cover product redesign and development, production line conversion, process tooling modifications, testing and performance evaluation, product trials, prototype testing, production line conversion, technical assistance and training, to convert one production line of capacity 100 units annually.

If successful, the demonstration project will contribute towards promotion of this technology for replacing two-stage HCFC-22 based refrigeration systems in cold storage and freezing applications and enable cost-effective conversions at other similar manufacturers in this sub-sector.

Programme Period:	Jau 2011-Jun 2012
Programme Component:	Energy & Environment
Intervention Title:	HCFC phase out in ICR (Yantai Moon Group Demonstration project)
Award ID:	00060894
Project ID:	00076877

Total resources required: $ 3,964,458

Allocated resources:

- Government
- Regular
- Donor MLF $ 3,964,458

Agreed by (FECO/MEP): ____________ Wen Wurui (Director General)

Agreed by (UNDP): ____________ Subinay Nandy(Country Director)

MULTILATERAL FUND FOR THE IMPLEMENTATION OF THE MONTREAL PROTOCOL ON SUBSTANCES THAT DEPLETE THE OZONE LAYER

PROJECT COVER SHEET - NON-MULTI-YEAR INVESTMENT PROJECTS

COUNTRY: CHINA

PROJECT TITLE:
Demonstration project for conversion from HCFC-22 technology to Ammonia/CO_2 technology in the manufacture of two-stage refrigeration systems for cold storage and freezing applications at Yantai Moon Group Co. Ltd.

IMPLEMENTING AGENCY:
UNDP

NATIONAL COORDINATING AGENCY: Foreign Economic Cooperation Office, Ministry of Environment Protection

LATEST REPORTED CONSUMPTON DATA FOR ODS ADDRESSED IN THE PROJECT:

A. Article-7 Data (ODP Tonnes for 2008, as of March 2010):

Annex-C, Group-I substances (HCFCs)	15,387.2

B. Country Programme Sectoral Data (ODP Tonnes for 2008, as of May 2009):

Substance	Total
HCFC-22	9,559.6
HCFC-141b	4,415.3
HCFC-142b	1,096.1
HCFC-123	7.3
HCFC-225ca	1.7
HCFC-225cb	0.2

ODS CONSUMPTION REMAINING ELIGIBLE FOR FUNDING (ODP Tonnes) :	N/A
CURRENT YEAR BUSINESS PLAN:	Included

PROJECT DATA

Sector:	Industrial and Commercial Refrigeration and Air Conditioning (ICR)		
Sub-sector:	Commercial and Industrial Refrigeration and Freezing Equipment		
ODS use in sector (2008* metric tonnes):			42,000
ODS use in sub-sector/application (2008* metric tonnes):			4,000
Project impact (metric tonnes):			250
Project duration:			18 months
Project Costs:	Incremental Capital Costs(including contingencies):	US$	2,757,158
	Incremental Operating Costs:	US$	1,207,300
	Total Costs:	US$	3,964,458
Local ownership:			100%
Exports to non-A5 countries:			0%
Requested grant:			**3,964,458**
Cost-effectiveness (US$/kg-ODS):			15.86
Implementing agency support costs:		US$	297,334
Total Cost to Multilateral Fund:		US$	4,261,792
Status of counterpart funding (Yes/No):			Yes
Project monitoring milestones included (Yes/No):			Yes

**Preliminary data based on ongoing surveys*

PROJECT SUMMARY

This demonstration project, upon successful completion, will establish the suitability of Ammonia/CO_2 technology as a viable replacement for HCFC-22 technology in the manufacture of integrated two-stage refrigeration systems for cold storage and freezing applications at Yantai Moon Group Co. Ltd.

The project will cover product redesign and development, production line conversion, process tooling modifications, testing and performance evaluation, product trials, prototype testing, production line conversion, technical assistance and training, to convert one production line of capacity 100 units annually.

If successful, the demonstration project will contribute towards promotion of this technology for replacing two-stage HCFC-22 based refrigeration systems in cold storage and freezing applications and enable cost-effective conversions at other similar manufacturers in this sub-sector.

Prepared by: UNDP in consultation with FECO and industry **Date:** January 2011

PROJECT OF THE GOVERNMENT OF PEOPLES REPUBLIC OF CHINA
Demonstration project for Ammonia/CO_2 cascade technology at Yantai Moon Group Co. Ltd.

Objective

The objective of this proposed demonstration project is to establish the suitability of Ammonia/CO_2 technology as a viable replacement for HCFC-22 technology in the manufacture of two-stage refrigeration systems for cold storage and freezing applications at Yantai Moon Group Co. Ltd.

Sector Background

The Industrial and Commercial Refrigeration and Air Conditioning (ICR) Sector in China has experienced remarkable growth in the past two decades, averaging at about 12% annually, due to the steep growth in the demand for consumer, commercial and industrial products, resulting from rapid overall economic development. This sector is categorized into several sub-sectors, namely: compressors, condensing units, small-sized air-source chillers/heat pumps, commercial and industrial chillers/heat pumps, heat pump water heaters, unitary commercial air conditioners, multi-connected commercial air conditioners, commercial and industrial refrigeration and freezing equipment, mobile refrigeration and air conditioning equipment and refrigeration and air conditioning components and parts. The 2008 estimated HCFC consumption in the sector based on ongoing surveys was about 42,000 metric tonnes.

The industrial and commercial freezing and refrigerating equipment sub-sector (including compressor condensing unit) covers applications widely used in food refrigeration, industrial refrigeration systems, fruit and vegetable preservation, food processing and infrastructure construction projects. With improving living standards, the demand for food processing and cold storages infrastructure is increasing at an annual rate of over 10%. Due to sustained economic development, oil and chemical industry, energy, construction and other infrastructure-related investments are rising rapidly, enhancing the demand in emerging market. The demand for industrial refrigeration equipment in pharmaceuticals, mine freezing, water dams and coal-bed gas liquefaction is also expanding. The current and potential demand for large-scale low-temperature freezing and cold storage equipment in all these fields is significantly high. In recent years, the average annual growth rate of large-scale industrial freezing and cold storage equipment has been over 15%. The total HCFC consumption in this sub-sector during 2008 was about 4,000 metric tonnes, making it one of the largest sub-sectors in the ICR sector.

Enterprise Background

Yantai Moon Group Co. Ltd. was established in 1956, specializing in manufacturing of air conditioning and refrigeration products and engineering design, installation, commissioning and technical advisory services in the areas of frozen foods, food processing, industrial refrigeration, central air conditioning and fruit and vegetable preservation technologies. In 1998, Yantai Moon Group Co. Ltd. was listed on Shenzhen Stock market. The enterprise has independent intellectual property rights for some models of its refrigeration compressor manufacturing technology. Yantai Moon Group Co. Ltd. is located in the Shandong province and employs 2,989 persons, of which 640 are technical staff. Yantai Moon Group Co. Ltd. focuses on self-reliance in technology development, but at the same time also has many partnerships with international companies, to bring the latest technologies into the Chinese market. Yantai Moon Group Co. Ltd. offers integrated systems for the following main applications:

Freezing and cold storage equipment: Packaged systems with open, semi-hermetic and hermetic screw compressors and also reciprocating compressors. The enterprise is the largest manufacturer of fresh fruit and vegetable processing equipment in China with a market share of about 60% in low-temperature refrigeration systems for cold storages and food processing equipment.
Industrial refrigeration systems: Yantai Moon Group Co. Ltd. is one of the largest manufacturers of integrated industrial refrigeration systems, such as large capacity brine chillers, ice makers, etc. based on screw compressors, with a 35% market share.
Central air-conditioning equipment: Based on screw and reciprocating compressor water chillers of large capacity, particularly specialized for large infrastructural projects like power plants, airports, etc.

Fresh Fruit and Vegetable Technology: Yantai Moon has multi-unit modular air-conditioned library technology for fresh fruits and vegetables preservation.

Yantai Moon Group Co. Ltd. is committed to technology innovation, focusing on environment protection, energy efficiency and safety. Over 70% of its refrigeration products use natural refrigerants.

In 2009 Yantai Moon Group Co. Ltd. manufactured the following HCFC-22 based integrated refrigeration systems:

No	Product Line	Evaporating temperature (°C)	Quantity (Nos.)	HCFC consumption (metric tonnes)
1	Water Chillers	+2	190	N/A
2	Brine Chillers	-15	320	N/A
3	Low-temperature secondary inlet	-25 to -40	120	N/A
4	Low-temperature two-stage	-35 to -55	100	250

Of the above the last, namely, two-stage low-temperature refrigeration systems (highlighted above), each with an average HCFC-22 charge quantity of about 2,500 kg, is the target for conversion in the current project.

Technology

The following factors need to be considered for selection of the alternative technology:

Technical factors
- Processing characteristics
- Functionality in end-product
- Proven and mature technology
- Energy efficiency

Commercial factors
- Cost-effectiveness
- Reliable availability

Health and safety factors
- Low risk for occupational health
- Low risk for physical safety (flammability, etc)

Environmental factors
- Direct ozone impacts
- Direct and indirect climate impacts

Some of the zero-ODP alternatives to HCFC-22 currently available for this application are listed below:

Substance	GWP	Application	Remark
Ammonia	0	Industrial refrigeration and process chillers	Flammability and toxicity issues. Material compatibility issues. Regulatory issues.
CO_2	1	Refrigeration in a secondary loop and in stationary and mobile air conditioning systems	Major redesign of system components needed. Investment costs are prohibitive
R-404A	3,260	Low temperature applications	High GWP, less efficient at medium temperatures, synthetic lubricants needed
R-507	3,900	Low temperature applications	High GWP. Azeotropic non-flammable blend of HFC-125 and HFC-143a. Refrigerating capacity comparable to R-502. Good heat transfer characteristics at low temperatures. Synthetic lubricants needed.

R-404A and R-507 both have high GWP and require synthetic lubricants, although their thermodynamic properties are suitable for low-temperature applications. Their long-term sustainability from an environmental perspective is considered doubtful.

Ammonia is a traditional natural refrigerant with good environment properties as well as favorable thermodynamic properties. The operating pressures are low, it has low flow resistance and it has excellent heat transfer characteristics. Being a single substance, it is chemically stable. It has high refrigeration capacity. It is widely available at affordable prices. However, ammonia is quite reactive; it is toxic and moderately flammable. It is also not compatible with non-ferrous materials.

CO_2 was a commonly used refrigerant in the late 19th and early 20th centuries, however its use gradually faded out with the advent of synthetic refrigerants. CO_2 has many favorable characteristics. It has no ODP and GWP of 1; it is inert, non-toxic and chemically stable, is compatible with almost all materials and available widely at affordable prices. For a given refrigeration capacity, the system components with CO_2 are much smaller compared to other refrigerants. However, the main disadvantage with CO_2 is its high operating pressures, which requires special designs for the system and components. CO_2 is also not very efficient at high pressure differentials.

Yantai Moon Group Co. Ltd. has selected a combination of Ammonia/ CO_2 in a cascade design as the technology of choice for its low-temperature two-stage integrated refrigeration systems, considering the favorable environmental and thermodynamic properties of these two alternatives.

Rationale for Technology Demonstration

As stated earlier, future market demand in China for food processing and related technologies and for industrial refrigeration is promising. The best operating evaporation temperature bracket for NH_3/CO_2 cascade refrigeration system is between -35 to -55°C, and this is the normal range for large-scale low-temperature industrial refrigeration applications. According to the industry statistics in 2008, the consumption of HCFCs in industrial and commercial freezing and refrigerating equipment (including compression condenser units) in China was about 4,000 metric tonnes, of which 1,200 metric tonnes were consumed in refrigerating equipment and systems with evaporation temperature between -35 and -55°C. NH_3/CO_2 cascade refrigeration system technology can effectively address the toxicity exposure issue of ammonia and therefore have more extensive application than pure ammonia refrigeration equipment and at the same time address technical issues relating to CO_2. Such technology can replace HCFC-22 in many applications, which have significant growth potential in the future.

Further, most of the large-scale low-temperature refrigeration systems use open-type compressors and open system design, with a significant amount of leakage and low recovery rate of refrigerant during maintenance, thus annual consumption of HCFCs in servicing for such systems is very high. Thus, replacing HCFCs in such applications gains high priority from an environmental standpoint.

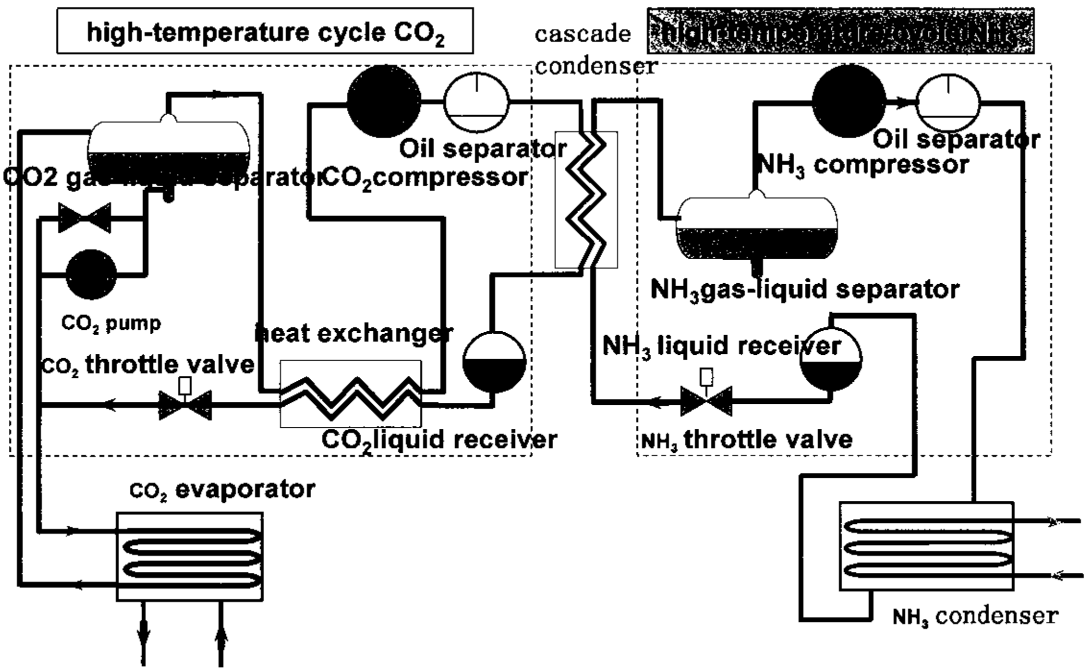
While NH_3/CO_2 cascade technology has been implemented elsewhere, its application has been sporadic and mainly focused on site-assembled custom-built legacy systems and not on a commercial production scale. China in general and Yantai Moon Group Co. Ltd. in particular, offer an opportunity for standardizing this technology on a commercial scale. This is because Yantai Moon Group Co. Ltd. manufactures integrated low-temperature refrigeration systems. Standardizing this technology in a factory-controlled environment will favor its widespread adoption considering the future growth prospects for its application. Thus, demonstration of this technology is considered critical for its early adoption and consequent dissemination to contribute to sustainable reductions in HCFC consumption as well as to contribute to protecting the climate system.

Project Description

Yantai Moon Group Co. Ltd. specializes in the manufacture of integrated packaged refrigeration systems incorporating twin-screw refrigeration compressors, of open and semi-hermetic designs. The present demonstration project will cover low-temperature (evaporating temperature range -35 to -55°C) applications, where the current two-stage HCFC-22 based designs will be replaced by NH_3/CO_2 cascade refrigeration system technology, using twin-screw refrigeration compressors.

Introduction

The NH_3/CO_2 cascade refrigeration system is constituted by two separate refrigeration circuits; the high temperature circuit and the low-temperature circuit. The low temperature circuit with CO_2 as refrigerant is used for the actual cooling. The high temperature circuit with NH_3 as the refrigerant is used to condense the CO_2 of the low temperature circuit. The two circuits are thermally connected to each other through a cascade condenser, which acts as an evaporator for the high temperature circuit and a condenser for the low temperature circuit. After absorbing heat from the brine in the CO_2 evaporator, the refrigerant CO_2 in the low temperature circuit is compressed in the CO_2 compressor, which increases the enthalpy of CO_2. The discharged CO_2 refrigerant from the compressor rejects the heat to NH_3 of the high temperature circuit in the cascade condenser. Then the cooled CO_2 refrigerant is throttled by the expansion valve, and enters the CO_2 evaporator. The heated NH_3 in the cascade condenser is compressed in the NH_3 compressor, which increases the enthalpy of NH_3. The discharged NH_3 refrigerant from the high temperature NH_3 compressor unit flows into the NH_3 condenser, in which NH_3 rejects the heat to the cooling water system or air cooled condenser. The relevant schematic is as below:



Unlike conventional low-temperature refrigerants, CO_2 has the characteristics of low evaporating temperature and high operating pressures. This presents challenges for the development of CO_2 low temperature systems:

- Intermediate-pressure compressor with CO_2 as the refrigerant must be developed
- Mid-pressure vessel for higher pressure must be designed and manufactured;
- The characteristics of CO_2, such as large unit volume refrigeration capacity and high latent heat, suggest higher requirements for the design of CO_2 heat exchangers;
- As some heat exchangers for the low-temperature side need to withstand high pressures, high stress under low temperature must be considered during the design;
- The optimal result that can be achieved by employing applicable circulation type;
- Severe corrosion for the low-temperature CO_2 system may be generated from the H_2CO_3 formed by reaction of CO_2 and water;
- Safety issues for running and shutdown of the NH_3/CO_2 cascade refrigeration system;
- The control system for the refrigeration system must be fully automatic, safe, efficient and reliable.

As already mentioned before, while the technical concepts underlying the design of NH_3/CO_2 cascade refrigeration systems are well-known, their factory-controlled standardization has not yet occurred on a commercial scale and this gap will need to be overcome in order to promote the wider adoption of this technology.

Current status of technology development

Yantai Moon Group Co. Ltd. has carried out initial development of NH_3/CO_2 cascade refrigeration systems with open-type twin screw compressors for large and medium commercial refrigeration and large industrial refrigeration applications, with a view to offer factory-manufactured integrated systems. The current status is as below:

- The twin-screw compressors are specially designed with the advantages of small size, light weight, smooth and safe operation at high speed. It can obtain high volume efficiency, low noise and little vibration. Stepless capacity control from 15% to 100% of the capacity can be achieved.
- Oil separator with indigenous patent is adopted. The separator has the advantage of efficient separation, which reduces oil content within the cascade refrigeration system. This gives full play to heat exchanger efficiency to ensure highly efficient operation of the refrigeration system.
- U-tube design for the system condenser evaporator is selected. The heat exchanger tube design is patented. This design has the advantage of high heat transfer efficiency.
- Liquid refrigerant pump enhances the heat exchange intensity of evaporator inner surface and raises heat transfer coefficient of the evaporator.
- Hot gas defrosting is utilized. Electronic expansion valve is used to control liquid flow, which can accurately regulate superheat to obtain good heat exchange.
- Intelligent and automatic control is adopted for the cascade refrigeration system, which can respond automatically to load changes and external conditions. Remote computerized monitoring system is employed. The refrigeration system has complete security protection devices and functions.

In October 2008, the design of NH_3/CO_2 cascade refrigeration system with twin screw compressors undertaken by Yantai Moon Ltd. passed technical appraisal by Shandong Science and Technology Agency. The appraisal group agreed that the project filled a technology gap, and that the product performance can achieve advanced levels and could be commercialized.

Feasibility

While the design of the NH_3/CO_2 cascade refrigeration system is based on conventional principles, the key elements in its operationalization and commercialization are the innovations needed to make the systems efficient, as well as to make them reliable by integrating system components optimally and manufacturing the integrated system in a factory-controlled environment. The present demonstration project will enable wider adoption of standardized, efficient and reliable factory-manufactured integrated NH_3/CO_2 cascade refrigeration systems.

Project activities

For the demonstration project, the existing product lines of compressor and pressure vessels will be modified to meet the industrial production capacity of three typical specifications of NH_3/CO_2 cascade refrigeration systems. To achieve this goal, the following activities will be carried out: Product and process redesign, Modification of production lines, Modification of test devices for product performance, Manufacturing of prototypes and Personnel training. After the modification, technology dissemination and documentation of the results would be carried out.

Product and process redesign

At present, the main product of the enterprise is the conventional refrigeration system with R-22 as the refrigerant. There is large difference in product design and production process between NH_3/CO_2 cascade refrigeration systems with twin-screw compressors and R-22 based refrigeration systems. To meet this need, the following redesign will be needed based on the existing production process: design of two typical specifications of CO2 compressors (see the table below), design of system components in the CO2 refrigeration system, and modification of the existing product lines of compressor and pressure vessels, design of test devices for CO2 refrigeration system, design of user demonstrations for the early users of NH_3/CO_2 cascade refrigeration systems.

The three specifications of CO2 screw compressors for the project are as below:

Model	Theoretical displacement (m3/hr)	Status
LG12R	152	Design completed
LG16R	300	To be developed
LG20R	600	To be developed

Two of the above (LG16R and LG20R) would be covered in the current project. The design elements would comprise of the following

- Design of screw compressor rotor profiles and structural design of compressor
- Design of high pressure vessel matching with CO2 screw compressor units
- Design of pressure vessels for high pressure, high-pressure low-temperature and other components matching with NH_3/CO_2 cascade refrigeration system with twin screw compressors
- Design of electric control and application software control
- Design of performance tests
- Design of demonstration for the first user of NH_3/CO_2 cascade refrigeration system

The process design would comprise of the following:

- Design of casting and forging manufacturing process for CO2 screw components;
- Design of CO2 screw compressor shell strength test device;
- Design of strength test device for CO2 pressure vessel of high-pressure low-temperature;
- Design of machining process includes design of CO2 compressor housing, rotors, oil pump parts and tube sheet of heat exchanger;
- Design of the welding technology of CO2 pressure vessel of high-pressure low-temperature, shell and tube heat exchanger;
- Design of CO2 finned tube air cooler for high pressure and low temperature process including design of outer shell sheet metal process and expanding tube process;
- Design of product assembly process, including assembly, pipe connections, air tightness testing
- Blank manufacturing of CO2 compressor components, including design of casting model, casting box, forging dies
- Design of CO2 finned tube of high-pressure low-temperature fin dies, dies baffle for punching, and half of the stamping dies for baffle;
- Design of special high-strength alloy machining tools for the high-strength components such as CO2 compressor housing, special measuring tools and special inspection equipment tools, including design of special cutter for compressor rotor machining, a variety of special boring tool and milling cutter for compressor shell processing, special boring tool for tube plate holes, fin-hole punch, as well as the design of special measuring tools and detection tools for machining process
- Special process equipments for CO2 compressor and high-pressure low-temperature CO2 pressure vessel, including fixtures for all kinds of mechanical processing (such as special fixtures of compressor rotor machining, and special positioning clamp devices of compressor shell machining.), positioning fixtures of welding and expansion joint, working sleeves matching with the products (such as set bit for compressor assembly, adjusting sleeve for end clearances of compressor rotors.) and station apparatus for turnover and store of parts;
- Design for modifying product line of the existing conventional refrigeration system, including processing arrangements, products site planning and special equipment layout for the added CO2 compressors and high-pressure low-temperature CO2 pressure vessels

Modification of production lines

The high temperature NH3 system in the NH3/CO2 cascade refrigeration system is the conventional product of Yantai Moon Group Co. Ltd. The existing product lines can be used for producing NH3 system components such as compressor, pressure vessel and heat exchanger.

The high pressure compressor and pressure vessel of high-pressure low-temperature for the CO2 low temperature system can be processed and manufactured by the general equipment and general tooling of the existing product line. To meet the production process requirements of the mid and low temperature and high pressure refrigeration system, the existing product lines of the compressor and pressure vessel are needed to be modified.

- Modification of the existing manufacturing lines of the NH3 and R22 compressors including rough castings production, rotor machining, housing processing, house strength test, the compressor assembly for the added CO2 compressors
- Modification of the existing manufacturing lines of the pressure vessels below the pressure of 20kg, including production process link of the added high-pressure low-temperature CO2 pressure vessel, such as CO2 oil separator, CO2 liquid receiver, oil filters, suction filters, tube processing and welding for shell and tube heat exchanger, oil cooler, cascade heat exchanger, CO2 regenerator, heat exchanger for defrost, tube expander, welding and assembly for CO2 shell and tube evaporator;
- Modification of manufacturing line for the existing 14kg fan heat exchanger, including processing of CO2 fin heat exchanger, shell sheet metal processing, expansion joint, welding, strength and air tightness testing;
- Added unit assembly of NH3/CO2 cascade refrigeration system with twin screw compressors, including the assembly of NH3/CO2 cascade refrigeration system and test of the air load factory;

The operating pressure of the existing compressor product line is below 20 kg. The design pressure of CO2 compressor is 50 kg in the NH3/CO2 cascade refrigeration system. To meet the high pressure of CO2 compressor in the project, the product lines of existing R22 compressor need to be modified.

- High-strength processing tool is needed because CO2 compressor housing material, rotor profiles and material, and all components materials are different from conventional products.
- The investment on special process equipments is made for the three specifications CO2 compressors, including compressor model, fixture and special inspection gauge of the rotor profiles.

The operating pressure of the existing pressure vessel for the refrigeration system product line is below 20kg. It belongs to the low-temperature, low-pressure pressure vessel even in the low temperature, while the design pressure of CO2 compressor is 50kg in the NH3/CO2 cascade refrigeration system. The low temperature vessel belongs to the high-pressure low-temperature pressure vessel in the CO2 system. The modification of product line for pressure vessels will be based on the existing one is the following:

- The materials of tube sheet and cylinder for the CO2 pressure vessels of high-pressure low-temperature are different from the conventional components materials. Therefore, the corresponding process equipments and control need to be added during production and test process, such as welding, expanding joint and inspection.
- The strength test and air tightness test are needed for the high-pressure low-temperature pressure vessel. And the test environment of cold shock in the low temperature also needs to be built up. Welding equipments of stainless steel container and high-pressure low-temperature vessel will be added, as well as welding test plate and assessment method of high-pressure low-temperature vessel.

Modification of test devices for product performance

As a new refrigeration system, the high temperature refrigeration system can be tested in the existing performance test laboratory after product commercialization, while the product test device of the CO2 refrigeration system requires new facility construction. The test devices of CO2 compressor housing strength and air load are to be added. In addition the following modifications/additions need to be done:

- Test instruments and meters
- Assembly test rig
- Installation and wiring for testing electricals
- Debug the test device
- Assessment of the test device by national professional agency

Manufacturing of prototypes

According to the industrialization requirement of the NH3/CO2 cascade refrigeration system, two specifications of refrigeration systems need to be developed based on the existing specification. Before commercialization, the prototype of refrigeration system needs to be manufactured and tested before mass production. As processing parts are numerous and processing precision is strict, the waste rate from casting to completion is very high. Four sets of rough parts need to be produced for each compressor size. One set of rough parts need to be manufactured for other auxiliary equipment. The prototype manufacturing will cover the following:

- Manufacture four sets of CO2 screw compressor prototypes for each specification of LG16R and LG20R.
- Manufacture one set of component matching with the cascade system for each specification.
- Refrigeration system prototype assembly.
- Experimental test on refrigeration system prototypes.

Personnel Training

The design, production, marketing and debugging of the new product are different from those of the conventional refrigeration system. Therefore, business unit training is needed for all sections of the project. The following personnel will be included in the training:

- Related designers, technicians.
- Production management persons, manufacturing workers.
- Product application engineer.
- Technician for installation and debugging, equipments maintenance personnel.
- Related user operators, equipment administrative personnel.

Technology Dissemination

According to user's requirements, design of the first demonstration application engineering for NH3/CO2 cascade refrigeration system with twin screw compressors will include scheme compilation, construction drawing design, details compilation of construction materials, instructions of installation and construction, instructions of debug operation.

Market promotion is needed for new technology entry in the market. A detailed work plan is needed in the market promotion as NH3/CO2 cascade refrigeration system with twin screw compressors is new to domestic refrigeration industry. The following methods will be used to promote the technology:

- Technical communication with engineering design companies, introduction of product, and promotion and recommendation plan.
- Technical communication with construction companies, product promotion and recommendation, and application technology.
- Application promotion in relevant industry associations.
- Organize product release conference, and display product and application technology.
- Communicate with government environmental protection departments to enhance publicity campaign.
- Advertisement and promotional brochures.
- Participate in exhibitions, such as International Refrigeration Exhibition in China, Chinese Fisheries Exposition, and Chinese Food Processing Exposition; display the product and application technology.
- Provide free technology, debug and maintenance to users of the demonstration project.

Summary

The conversion will be carried out in close consultation with FECO/MEP, industry associations, scientific and technical institutions and the special working group for the ICR sector.

Project Costs

Incremental Capital Costs

The total incremental capital costs amount to US$ 2,757,158. Details are provided in Annex-I.

Incremental Operating Costs

The agreed total incremental operating costs calculated for one-year duration amount to US$ 1,207,300. More details are provided in Annex-I.

Total Project Costs

The agreed total project costs amount to US$ 3,964,458.

Financing

The requested MLF grant is **US$ 3,964,458**, which represents eligible incremental costs, not including agency support costs.

Implementation

Project Monitoring Milestones

MILESTONE/MONTHS	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Start-up of project activities	X																	
Submission of project document for signature	X	X																
Project document signature		X	X															
Preparation and request for bids			X	X														
Award of contracts				X	X	X												
System design and compressor design	X	X	X	X	X	X	X	X										
Stainless vessel processing equipment	X	X	X	X														
Design of testing lab and procurement of material	X	X	X	X														
Processing of casting model and boxes for compressor parts					X	X	X	X										
Installation of testing equipment					X	X	X	X										
Processing of vessel parts for testing equipment					X	X	X	X										
Prototype manufacturing of compressors					X	X	X	X										
System drawings									X	X	X	X						
Fixtures and cutters for CO2 compressor									X	X	X	X						
Conversion for U-tube processing									X	X	X	X						
Installation and tuning of testing equipment									X	X	X	X						
Assembly of compressors									X	X	X	X						
Retrofitting of testing device for CO2 compressor													X	X	X	X		
Modification of production line													X	X	X	X		
Verification of testing lab													X	X	X	X		
Completing the prototype system													X	X	X	X		
Market survey and obtaining the certificates																	X	X
Installing air load testing equipment																	X	X
Training and technical assistance																	X	X
Verification																	X	X

Payment Schedule

Schedule (Predicted date)	Payment Conditions	Amount (US$)	Accumulated Amount (US$)
1st Payment (January 31 2011)	Upon signing of the contract	1,000,000	1,000,000
2nd Payment (August 31 2011)	Completion of high pressure test equipment for CO2 vessel	1,200,000	2,200,000

3rd Payment (Mar 31 2012)	Completion of prototype building, and completion of testing equipment	800,000	3,000,000
4th Payment (June 30 2012)	Completion of training, technology dissemination, and verification of project	865,169	3,865,169

Management

The project will be under the overall management and coordination of the Foreign Economic Cooperation Office, Ministry of Environment Protection of China. UNDP will be the implementing agency for the project, which will provide international coordination and technical assistance as needed.

The project employs the Performance-based Payment (PBP) mechanism in its implementation. Under the PBP mechanism, the enterprise tasked to carry out the conversion would play the role as a key executer, which is responsible for all the activities related to the conversion (with supervision of the technical expertise team hired by FECO and/or UNDP), including but not limited to: product redesign, procurement of raw material, components, equipments and consulting services as per the budget allocation table, modification of production lines and product testing devices, etc., trial operation of production lines, and project technical commissioning. The procurement shall be organized fully in line with the marketing principle, so that the goods and services procured are high quality, most reasonable price and suitable for product line conversion to make sure the new alternative technology applied feasibly and successfully. The detailed arrangement on procurement will be defined in the contract between FECO/MEP and the Executor (enterprises).

FECO and UNDP will not be involved in the procurement activities of the enterprise by any means other than make payment to the enterprise in tranches for the costs of procurement and conversion, at agreed payment dates given in the payment schedule, and when milestones prerequisite for the tranche have all been achieved on time.

Verification

1) **Periodical Performance Verification.** Before each payment, FECO will invite independent experts to verify whether the performance for each milestone that the payment depends on have been satisfying. The verification reports will be submitted and accepted by UNDP as the main supporting documents for requesting the installment of payment.

2) **Technical Assessment.** Before the last installment of payment, FECO and UNDP will invite independent experts to verify whether the selection and application of alternatives in practice are suitable and feasible. The assessment report will be submitted to FECO and UNDP.

M&E

1) FECO and UNDP will organize a joint Monitoring and Evaluation mission to the Project executer during this project operation. The mission can be combined with the verification mission accordingly. The M&E schedule will basically follow the timeline of payment schedule.

2) NEX Audit will be organized by UNDP during the project implementation upon UNDP's audit arrangement in the project years. For any issue identified during the auditing process, FECO shall take corresponding correction/improvement measures as per the audit findings and recommendation. Meanwhile, the payment may be suspended depending on the nature of the issues concerned until the acceptable/satisfactory results are worked out.

3) Quarterly Review and Annual Review Meeting will be organized by FECO; Semi-annual Project Review Reports and a final Project Report will be submitted to UNDP at least 10 days before the review meetings and by the end of project operation in 2012.

Impact

The successful implementation of this demonstration project will provide an environmentally safe and cost-effective alternative for enabling replication of this technology in similar applications in this sector in China and facilitate HCFC reductions for compliance with the 2013/2015 control targets.

The project will result in direct reductions of 250 metric tonnes of HCFC-22 usage at Yantai Moon Group Co. Ltd. Over a 15-year life-span of the refrigeration systems manufactured by the enterprise and covered by this project, direct and indirect emission reductions amounting to about **1.66 million CO_2-eq tonnes** will be achieved, thus contributing to protection of both the ozone layer and the climate system.

ANNEX-I
Incremental Cost Calculations

Incremental Capital Costs

No	Cost Head		Amount (US$)
1	**Product and process redesign**		291,912
	System	System redesign (US$ 22,912)	
	Process	Process redesign (US$ 21,000)	
	Compressor	Compressor redesign (US$ 150,000)	
	Software	Heat exchange analysis software (US$ 80,000)	
	Certification	Testing and certification (US$ 10,000)	
	Miscellaneous	Documentation and research (US$ 8,000)	
2	**Modification of production lines**		1,183,000
	Compressor (US$ 832,852)	Compressor parts casting model (US$ 123,544)	
		Compressor parts casting box (US$ 33,235)	
		Tooling for CO2 compressor (US$ 151,588)	
		Measuring and inspection tools (US$ 58,603)	
		CO2 compressor machining tool (US$ 360,735)	
		CO2 compressor casing test device (US$ 29,265)	
		Co2 compressor air load test device (US$ 75,882)	
	Pressure vessels (US$ 350,148)	Equipment for stainless steel parts (US$ 102,941)	
		Tooling for stainless steel containers (US$ 8,088)	
		High-pressure testing of CO2 vessels (US$ 45,588)	
		Testing for CO2 U-tube (US$ 5,882)	
		Tooling for CO2 U-tube (US$ 39,706)	
		Development cost for CO2 U-tube (US$ 7,353)	
		CO2 high pressure air drying system (US$ 20,588)	
		Magnetic flaw detector for CO2 vessels (US$ 16,029)	
		Universal shock testing for CO2 vessels (US$ 2,941)	
		Impact testing for CO2 vessels (US$ 3,971)	
		Low-temperature test room (US$ 63,237)	
		Welding test plate for CO2 vessels (US$ 33,824)	
3	**Modification of test devices for product performance**		688,142
	Test devices	Materials and installation of test devices (US$ 167,073)	
	Pressure vessel parts	Components of pressure vessels ten types (US$ 439,876)	
	Instruments	74 different test device instruments (US$ 19,134)	
	Software	Test software and debugging (US$ 51,471)	
	Consumables	Refrigerant and lubricants (US$ 1,765)	
	Commissioning	Test device commissioning (US$ 8,823)	
4	**Manufacturing of prototypes**		474,095
	CO2 compressor	Four sets/specification x 2 specifications (US$ 118,897)	
	Pressure vessels	Matching pressure vessels and parts (US$ 58,529)	
	Pressure vessels	System pressure vessels (US$ 158,224)	
	Ammonia system	High temperature ammonia system (US$ 120,798)	
	Controls	Electrical and other controls (US$ 17,647)	
5	**Personnel training**		51,764
	Training	Training for about 300 persons (US$ 51,764)	
6	**Technology dissemination**		64,412
	Workshop	Technology dissemination workshop (US$ 24,412)	
	Communication	Technology communication (US$ 30,000)	
	Events	Participation in exhibitions (US$ 10,000)	
7	**Contingencies**	For enterprise	58,611
8	**Technical assistance**		68,000
	Report on project results & Technology Dissemination	Monitoring/Evaluation/Verification; Technical Commission/ Project Acceptance; Technology dissemination, etc. (US$ 28,000)	
	National experts	Throughout project implementation (US$ 20,000)	
	International experts	Throughout project implementation (US$ 20,000)	
9	**ISS for FECO**		118,933
10	**ISS for UNDP**		79,289
Total			**3,078,158**
Among which paid by counterpart funding by the enterprise			**321,000**
Total by MLF funding			**2,757,158**

Incremental Operating Costs

The replacement of R-22 two-stage refrigeration systems by NH3/CO2 cascade refrigeration systems with twin screw compressors requires redesign of systems and high-strength materials are needed for CO2 high-pressure system. These factors result in increased costs. At the same time, CO2 replacing R22 will reduce the installed capacity, which decreases the material cost to a certain extent.

The high-strength material is needed for the high pressure of CO2 refrigeration system in the NH3/CO2 cascade refrigeration system, with similar designed pressure of matching bearings and shaft seal. Therefore, the material expense and manufacturing cost will increase as a result.

The pressure vessels in the system are high-pressure type or high-pressure low-temperature type. Stainless steel will be adopted. Special equipments for welding technology and expanding connection process will be needed. Meanwhile, special test technology of pressure vessel will be needed for the high-pressure low-temperature pressure vessel. Therefore, material expense and manufacturing cost will increase.

The refrigerant charge for the NH3/CO2 cascade refrigeration system is smaller and the CO2 price is lower. Due to the large volumetric refrigerating capacity of CO2, the installed capacity of CO2 screw compressor in the NH3/CO2 cascade refrigeration system is smaller than that for the existing two stage compression refrigeration system. This will reduce the increased cost of CO2 compressor material to some extent.

The cost for the baseline HCFC-22 based two-stage systems are summarized as below:

No.	Item	Cost (US$)
1	Low pressure screw compressor units	21,250
2	High pressure screw compressor units	14,779
3	Condenser	8,853
4	Siphon tank	1,338
5	High-pressure liquid receiver	2,470
6	Intercooler	1,853
7	Low-pressure cycle barrel	3,706
8	Canned motor pump	1,176
9	Piping and auxiliary materials	9,750
10	Valve	4,368
11	System control cabinet	3,176
Total		**72,720**

The cost for the NH3/CO2 cascade systems to replace the above would be as below:

No.	Item	Cost (US$)
1	NH_3 screw compressor units	15,000
2	Condenser	8,852
3	NH_3 liquid receiver	1,030
4	NH_3 oil receiver	250
5	CO_2 screw compressor units	15,808
6	CO_2 condenser evaporator	5,206
7	CO_2 gas-liquid separator	3,294
8	CO_2 Low-temperature cryogenic pumps	2,030
9	CO_2 liquid receiver	2,470
10	CO_2 heat exchanger	3,118
11	CO_2 auxiliary heat exchanger	2,059
12	Heat exchanger for defrosting	1,765
13	Heat source pump for defrosting	1,471
14	Auxiliary cooling units	4,426
15	Piping and auxiliary materials	6,338
16	Valve	7,794
17	System control cabinet	3,882
Total		**84,793**

Based the above, the manufacturing cost of HCFCs two stage compression refrigeration system is US$ 72,720 per unit, and that of the NH_3/CO_2 cascade refrigeration system is US$ 84,793 per unit. Thus, the incremental operating cost per product is US$ 1,207,300.

Total Project Costs

Cost Head	Amount (US$)
Incremental Capital Costs (including contingencies)	2,757,158
Incremental Operating Costs	1,207,300
Total	**3,964,458**